

Rock Types and Identification of Tight Oil Reservoir of Salt Lake in Continental Facies : A Case Study of Permian Lucaogou Formation, Jimsar Sag

Ma Ke¹hou Jiagen¹ Liu Yuming¹ Shi Yanqing¹

(1 College Of Geosciences, China University Of Petroleum, Beijing, 102249, China ;Funded by National Basic Research Program of China (973) (No.2015CB250901)

Abstract : The new century has witnessed a strategic breakthrough in unconventional oil gas. Hydrocarbon accumulated in micro-/nano-scale pore throat shale systems has become an important domain that could replace current oil&gas resources. Unconventional oil gas plays an increasingly important role in our energy mix. Petrology and pore characteristics of the tight oil reservoir in the Lucaogou Formation, Jimusar Sag, were carefully studied by core observation, thin section identification, and EMPA analyses, with reference to outcrop profiles, and logging and seismic data. The results show that tight reservoir rocks are characterized by complex mineral compositions and multiple rock components, the reservoir section was heterogeneous and mainly consisted of rhythmically interbedded dolomite/siltstone and mudstone. The dolomitic siltstone were most widely distributed and served as the main reservoir rocks of the upper and lower reservoir segments of the Lucaogou Formation. Based on the research on rock component types and characteristics, we divided three major types include terrigenous detrital rocks, carbonate rocks, pyroclastic rocks, and further 7 subclasses through lithology, physical property, oiliness and guiding of sedimentology, and then we built the adaptability of lithology identification chart, which better solves the problems in logging lithology identification.

Keywords: Jimsarsag; tight oil; conventional logging; lithology identification

I. Introduction

Under the innovation of new theory and new technology, the unconventional oil and gas exploration and development will get more and more breakthrough, and has become an important part of the global oil and gas supplies^[1]. The tight oil in China has wide distribution and big geological resource, it has presented a good exploration prospect^[2]. Especially the tight oil in Jimsar sag of Junggar Basin has become the key blocks of tight oil exploration and development, this block got an important breakthrough in exploration work in recent years^[3].

The Jimsar sag located off the southeast of the Junggar basin, the area of its structural is 1287km². The Permian Formation in the Jimsar sag can be divided into four formation segments from down to up, include Wulabo Formation, Jingjingzi Formation, Lucaogou Formation and Hongyanchi Formation, and the Lucaogou Formation is the major target of tight oil. The Lucaogou Formation can be divided into upper segment (P₂l₂) and lower segment (P₂l₁). The two segments in Lucaogou Formation also can be divided into two sand groups, the sand group of P₂l₂² and P₂l₁² are the major development formation of tight oil. The thickness of P₂l₂ is bigger than P₂l₁, mainly between 50 and 140m, and the thickness of P₂l₁ is mainly between 30 and 60m^[4].

II. Research Situation In Research Area

The correlational research has been carry out by scholars at home and abroad involve the petrology characteristics, the genetic model and the distribution patterns of fine-grained sedimentary. The research of Chinese scholars focus on the basic research include composition of clay minerals content and hydrocarbon generation evaluation. The fine-grained sediment research concentrate on the marine sediment and lake facies^[5,6]. The type and lithologic characteristics are the foundation of the fine-grained sedimentary. As the typical continental tight oil, the Lucaogou Formation's basic geological research is still relatively weak. The division of rock type and recognition remains controversial^[7]. Therefore, this paper combined core observation with slice analysis, conducted a relevant study in rock types and characteristics of tight oil in Lucaogou Formation, established a lithology recognition method, which better solves the problems in logging lithology identification.

A. Basic Research

A. Rock classification of tight oil reservoir

The well J174 in Permian Lucaogou Formation, Jimsar sag has complete core, accumulated 256m. A detailed study was performed on rock types and characteristics by taking the tight oil reservoirs of Well J174 as the research target. The test results has stronger comparative and better vertical continuity, which offered basic data

support for rock classification of tight oil reservoir.

a. Mineral composition characteristics

It is characterized by complicated mineral compositions and ore fabrics in The Permian Lucaogou Formation, include quartz, potassium feldspar, anorthose, calcite, dolomite, hematite, analcite, clay and so on. The feldspar has the highest percentage and the clay has the lowest percentage, while the percentage of quartz is equal to dolomite. It shows that the rock types of tight oil reservoirs are dominated by carbonate rocks and terrigenous detrital rocks, while certain segments contain a small number of pyroclastic rocks and normal mixed sedimentary rocks.

b. Rock components types

The analysis from casting lamella shows that the rock composition in Lucaogou Formation is much more complicated than other sedimentary rocks. Terrigenous detrital components, carbonate components and pyroclastic components can appear in the same rock stratum.

In the different layer, the relative amount of terrigenous detrital can range from 0 to 100%, and its average content is 52.8%, while the discrepancy is small between different range of content. In the mineral compositions, terrigenous detrital components shows the characteristics of low compositional maturity and low quartz content.

Compared with terrigenous detrital components, the carbonate components' average content is 37.7%, while the discrepancy is big between different range of content. In small part, the content of carbonate components can reach 90%, which constituted the main rock component types. Through mineral constituent analysis, the carbonate components is mainly Micritic dolomite.

Due to the Volcanism in Permian, it is resulted that pyroclastic components widespread in the Lucaogou Formation^[8]. The pyroclastic components shows its own characteristics, include finer particle, larger difference of relative content distribution. Compared with the former components, the main distribution range is between 0 and 30%, while has the largest discrepancy between different range.

The pyroclastic components can make a contribution to improve the reservoir physical properties^[9]. In general, there are many soluble constituents which can form secondary pores through dissolution by organic acid. In another side, micro-fracture will formed during the devitrification process^[10].

c. Rock classification scheme

Many scholars have put forward their own solutions in mixed sedimentary rocks' classification^[11]. But on account of the complex components, the existing classification scheme couldn't divide the rock types effectively. Therefore, we need to apply a new method which based on the previous classification scheme to divide the complex mixed sedimentary rocks and offer theoretical support for Jimsar sag in tight oil exploration and development.

Based on the research on rock component types and characteristics, the contents of terrigenous detrital, carbonate and pyroclastic debris are taken as "three end-members" to form the dividing scheme. Then took the reservoir physical property, oiliness, logging identification and sedimentary guidance as principle, the tight oil reservoir rock types are divided into three major types, and further 7 subclasses, include tuffite, dolomitic siltstone, arene siltstone, mudstone, silt dolomite, micritic dolomite and limestone. Because of many wells in Jimsar sag didn't core, it is important to consider the logging identification of classification scheme, in the hope to apply various log curves to identify the rock type in the wells which didn't have cores.

B. Lithology Identification Method

The lithology and mineral composition of the tight oil reservoir in Lucaogou formation of Jimsar sag are complex and diverse, and majority of them are transition rock between clastic rock and carbonate rock^[12]. It is difficult to identify rock types by one or two logging curves. Generally speaking, the SP curve, GR curve and 3 porosity log curves can't identify rock types effectively. Through the numerical statistics in seven kinds of conventional logging curve, it is concluded that the curve of GR, RT, DEN, AC and CNL has a high sensitivity in terrigenous detrital components, carbonate components and pyroclastic components, while the SP curve couldn't identify rock types effectively.

Based on the rock classification and logging sensitivity analysis, the logging Fisher discrimination method has been established. First of all, the logging curve should be smoothed a little. Then, we should read curve value which belong to the same lithology. Finally, geophysical logging data must be normalized to guarantee a unified scale in research area.

According to the ordinary resolution of logging curve, the sample points should be chosen from single lithology which thicker than 0.5m, while single lithology which thinner than 0.5m can't be identified effectively. Based on the well J174, 3174 sample points had been chosen from five kinds of logging curves. IBM

spss 19 is a frequently-used software for mathematical statistics, after the sample data imported, Then chose the Fisher discrimination method as well as modified regulation parameters to receive multiple judgment result. The function which has the highest accuracy will be the discriminant function of lithology and the discrimination formula as follows.

Tuffite : $-315.513-4.264X_1-0.087X_2-0.901X_3+3.006X_4-0.998X_5$

Dolomitic siltstone : $-252.807-3.520X_1-0.077X_2-0.925X_3+3.341X_4-1.062X_5$

Silt dolomite : $-207.203-2.956X_1-0.061X_2-0.953X_3+3.133X_4-0.667X_5$

Limestone : $-331.496-3.641X_1-0.073X_2-0.856X_3+3.932X_4-1.328X_5$

Micritic dolomite : $-354.378-4.589X_1-0.097X_2-0.899X_3+3.686X_4-1.729X_5$

Arene siltstone : $-302.564-3.123X_1-0.082X_2-0.971X_3+3.738X_4-1.072X_5$

Mudstone : $-271.218-3.261X_1-0.067X_2-0.824X_3+3.496X_4-1.639X_5$

X_1 : GR ; X_2 : RT ; X_3 : DEN ; X_4 : AC ; X_5 : CNL (according to the maximum results of each lithofacies discriminant for lithology classification).

Through the discrimination function above to examine the sample data from J174, we got the accuracy of seven lithology. The accuracy of tuffite, dolomitic siltstone, arene siltstone, mudstone, silt dolomite, micritic dolomite and limestone respectively are 75.6%, 78.7%, 79.7%, 86.1%, 69.7%, 81.2%, 79.4%. At the same time, other cored wells were also examined by the method, and the rate of identification is between 70% and 81%. The comparative analysis between core and lithologic identification results shows that thicker lithology has higher accuracy. The lithology identification method laid a good foundation for the subsequent geological research.

C. Others

In order to be able to carry out the comprehensive geological research of tight oil better, many laboratory, research center and other institutions in China devote themselves to the study of unconventional oil and gas resources. At the same time, China has set up many national level research project such as "973" program and mega project of science research, and these projects will offer a bigger communication platform and a broad space for development for unconventional oil and gas resources.

III. Research Prospects

The Chinese continental tight oil reservoir mainly form from fine-grained sedimentary environment such as delta front-prodelta-semideep lake, and it has a big different from coarse-grained sedimentary environment which composed of river-alluvial fan-deltaic plain. Therefore, it is important to carry out the research of lithology identification and sedimentation mechanism in continental facies, and study the sedimentation and its progress which based on the fine-grained lithology identification. All the research contents above will make a great contribution to the enrichment region selection and distribution prediction of unconventional oil and gas resource.

IV. Conclusion

- 1) The tight oil reservoir rocks in Permian Lucaogou Formation of Jimsar sag are characterized by complex mineral compositions and multiple rock components, classified as transitional mixed sedimentary rocks.
- 2) The contents of terrigenous detrital, carbonate and pyroclastic debris are taken as "three end-members" to form the dividing scheme and divided the reservoir rocks into three major types, and further 7 subclasses, include tuffite, dolomitic siltstone, arene siltstone, mudstone, silt dolomite, micritic dolomite and limestone.
- 3) Based on the lithology classification, conventional logging Fisher discrimination method has been established which has strong ability of identification and higher identification accuracy.

References

- [1]. Jia Chengzao, Zheng Min, Zhang Yongfeng. Unconventional hydrocarbon resources in China and the prospect of exploration and development[J]. Petroleum Exploration and Development, 2012, 39(2): 129-136.
- [2]. Li Jianzhong, Zheng Min, Zhang Guosheng, et al. Potential and prospects of conventional and unconventional natural gas resource in China[J]. Acta Petrolei Sinica, 2012, 33(S1): 89-98.
- [3]. Wang Chengyun, Kuang Lichun, Gao Gang, et al. Difference in hydrocarbon generation potential of the shaly source rocks in Jimsar, Permian Lucaogou Formation[J]. Acta Sedimentology Sinica, 2014, 32(2): 385-390.
- [4]. Kuang Lichun, Hu Wenxuan, Wang Xulong, et al. Research of the Tight Oil Reservoir in the Lucaogou Formation in Jimusar Sag: Analysis of Lithology and Porosity Characteristics [J]. Geological Journal of China Universities, 2013, 19(3): 529-535.
- [5]. Deng Hongwen. The genetic types and association evolution of deep lacustrine facies mudstones[J]. Acta Sedimentology Sinica, 1990, 8 (3): 1-21.
- [6]. Jiang Zaixing, Liang Chao, Wu Jing, et al. Several issues in sedimentological studies on hydrocarbon-bearing fine-grained sedimentary rocks[J]. ACTA PETROLEI SINICA, 2013, 34(6): 1031-1039.
- [7]. Xi Kelai, Cao Yingchang, Zhu Rukai, et al. Rock types and characteristics of tight oil reservoir in Permian Lucaogou Formation, Jimsar sag[J]. ACTA PETROLEI SINICA, 2015, 36(12): 1495-1507.
- [8]. Meng Yuanlin, Zhu Hengdong, Li Xinning, et al. Thermodynamic analyses of dolomite dissolution and prediction of the secondary porosity zones: A case study of tight tuffaceous dolomites of the second member, Permian Lucaogou Formation reservoir, Santanghu

- Basin, NW China[J].Petroleum Exploration and Development, 2014, 41(6):690-696.
- [9]. Wang Hongyu, Fan Tailiang, Xiao Yingying, et al. Effect of tuffaceous components on physical property of sandstone reservoir[J].ActaPetroleiSinica, 2010, 31(3): 432-439.
- [10]. Wang Jianwei, BaoZhidong, Chen Mengjin, et al. Differentiation of sandstones' tuff fillings and its effect on porosity-An example from the Paleozoic sandstones in Northwestern Ordos[J]. Chinese Journal of Geology, 2005, 40(3):429-438.
- [11]. Wang Jieqiong, Liu Bo, Luo Ping, et al.Classification and genesis of Sinianmixed sedimentite from northwest margin of Tarim Basin, China[J]. Journal of Chengdu University of Technology :Sci&Technol Ed, 2014, 41(3): 339-346.
- [12]. KuangLichun, Sun Zhongchun, OuYangmin, et al. Complication Lithology Logging Identification of the Lucaogou Tight Oil Reservoir in JimusaerDepression[J].WELL LOGGING TECHNOLOGY, 2013, 37(6) :638~642.